As will be seen by the above table, the precipitation over the section under discussion was considerably above the average for November, but the weather was abnormally warm and a greater portion than usual of the precipitation fell as rain, and it was instrumental in increasing the volume of water in the Snake and the Columbia rivers above the monthly average. The November snowfall contributed but little to the winter's accumulated depth, but in January and February, with more than the usual amount of snowfall and temperatures below the normal, the snow depth increased probably beyond the usual amount. Spring opened earlier than usual, and March with temperatures much above the normal, caused, as already mentioned, the snow in exposed places to melt rapidly, resulting in high water in all streams during that month, and causing apprehension for an unusual volume of water in the Columbia during the annual rise.

April was exceptionally warm, and the mountain snows continued to melt rapidly; and as will be seen by the accompanying hydrograph, the Columbia and the Snake rivers began to rise in their lower courses about the 7th and continued to rise without any marked interruption until the end of the month. The flood stage, however, was not reached at any of the gaging stations, although at Vancouver, Wash., the gage registered only 0.1 foot short of the flood stage, and at Portland, on the Willamette, backwater from the Columbia caused a stage of 16.3 feet, which is 1.3 foot above the flood stage. Backwater affects the stage of the Willamette at Portland to such an extent that there is a marked similarity in comparative stages of the two rivers at Vancouver and Portland, respectively; hence the flood crests at Portland, as given in Table 4, show quite accurately the stages of the lower Columbia throughout its course.

TABLE 4.—*Flood crests at Portland, Oreg., during annual rise of Columbia River.*

| Year. | Stage. | Year. | Stage. | Year. | Stage. | Year. | Stage. |
|---|---|---|---|---|---|---|---|
| 1879 | 19.3 | 1887 | 25.7 | 1895 | 16.3 | 1903 | 24.0 |
| 1880 | 27.3 | 1888 | 18.2 | 1896 | 23.8 | 1904 | 20.8 |
| 1881 | 19.7 | 1889 | 10.0 | 1897 | 23.7 | 1905 | 13.6 |
| 1882 | 26.1 | 1890 | 20.1 | 1898 | 20.7 | 1906 | 13.4 |
| 1883 | 17.8 | 1891 | 14.1 | 1899 | 24.2 | 1907 | 19.2 |
| 1884 | 20.2 | 1892 | 19.3 | 1900 | 17.8 | 1908 | 21.2 |
| 1885 | 14.5 | 1893 | 22.0 | 1901 | 20.8 | 1909 | 21.4 |
| 1886 | 20.0 | 1894 | 33.0 | 1902 | 20.7 | 1910 | 19.1 |

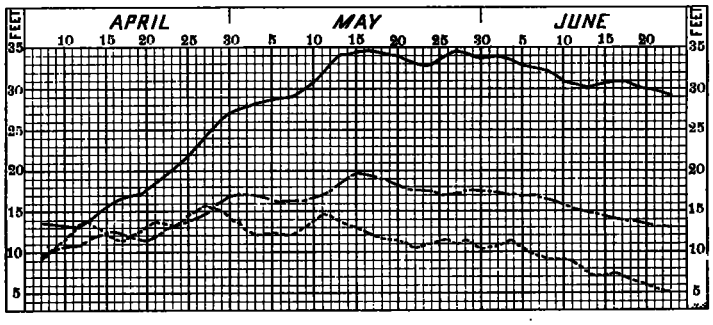


FIG. 1.—Hydrograph showing successive stages of the Columbia and Snake rivers at three representative stations in District No. 12.
———— Wenatchee, Wash., Columbia River.
– – – – – – Vancouver, Wash., Columbia River.
. . . . . Lewiston, Idaho, Snake River.

The highest stages along the Snake River were reached during the last 3 days of April, but there was a secondary rise during the first half of May, which increased the stages along the lower Columbia, and the highest stages along the Columbia River were generally recorded on May 14 to 16. The following table shows the highest recorded stages, with dates of occurrence at all stations on the Snake and Columbia rivers.

River navigation was not materially interfered with during the rise, except from May 12 to 18, inclusive, when the highest stages were recorded along the lower Columbia. At this time the current was so strong at Cascade Locks that boats, full-freighted, could not ascend the river, and were compelled to return to Portland and discharge a portion of their cargoes before passing the locks. The locks close at a stage of 34 feet, as registered at The Dalles, and a stage of 31 feet at the last-named point gives a current too strong for boats of the present type to overcome; more powerful boats would, however, have experienced no difficulty in making regular trips during this time. Navigation on the Snake River is never impeded by high water.

TABLE 5.—*Annual rise Columbia River, 1910, highest water and dates of occurrence.*

| Stations. | Height | Date. | Stations. | Height | Date. |
|---|---|---|---|---|---|
| Weiser | 10.5 | April 28, 29, 30. | Kennewick | 16.5 | May 14. |
| Lewiston | 15.6 | April 27. | Umatilla | 19.9 | May 14. |
| Riparia | 14.8 | April 28. | Celilo | 16.3 | May 14. |
| Bonners Ferry | 24.4 | May 12. | The Dalles | 33.1 | May 14. |
| Newport | 15.7 | May 16, 17, 18. | Cascade Locks | 25.9 | May 15. |
| Northport | 22.9 | May 29, 30. | Vancouver | 19.6 | May 15, 16. |
| Wenatchee | 34.8 | May 16, 27. | Portland | 19.1 | May 15, 16. |

Throughout the rise the stages of the river at Portland were quite accurately foretold, and, acting on this timely information, perishable goods were removed to places of safety, and other precautionary measures were taken to minimize the danger as far as the interests affected were concerned. As no reported damage occurred, it is obvious that the warnings have been of great value in protecting property interests. At Portland the river was above the flood stage from April 28 to June 10, a period of 43 days, and at highest water was 4.1 feet above that stage.

## FROST FIGHTING IN THE BOISE VALLEY.

By EDWARD L. WELLS, Section Director

The spring of 1910 was a favorable one for the fruit growers in the Boise Valley, and an unfavorable one for making experiments in protecting crops from frost. There was but one serious frost, and partly because of extensive use of orchard heaters, and partly because of the fact that this frost came so early (April 15) that the buds and blossoms of commercial fruits had not yet reached the most tender stage, little damage resulted.

For the first time in the history of the valley, oil heaters were used by fruit growers. They were purchased in car lots, as was also the fuel oil for use in them. The Weather Bureau was in constant touch with the growers, rendering valuable assistance in critical times, but could have been of much greater assistance had the growers themselves been better organized. The office was kept open all night on 11 nights, and part of the night on a number of others. The plan was to keep open whenever there was any cause for uneasiness, and this plan saved the growers much time and energy in watching, and a considerable amount of material.

On the night of April 14–15, Mr. Arthur W. Garrett, formerly an assistant observer in the Weather Bureau, and now manager of the Garret Mercantile Company, at Meridian, 10 miles west of Boise, spent the night in the orchard of Mr. W. N. Yost. He has kindly furnished this office with a report of his observations, extracts from which are given below:

The first observation of temperature, at 12:30 a. m., showed a reading of 28°. Several observations were taken between 12:30 and 2:30, the temperature fluctuating considerably, probably due to changes in the direction of the wind. The readings varied from 26° to 31°. While the wind shifted considerably during the night, it was generally from a westerly direction during the fore part of the night, and from an easterly direction during the latter part. There was a noticeable breeze at times, but toward morning it was generally quiet.

At 2:30 a. m. the lighting of the pots was commenced, at which time the temperature in the orchard stood at 26°. At first only about half the pots were lighted, the lids being pulled back about one-third. Several observa-

tions were taken during this period, the readings remaining practically uniform at 26°. At 4 a. m. the temperature dropped suddenly to 23°. By this time all the pots were lighted and the lids were opened back halfway, and the smoke in the orchard became very thick and did not drift much.

At 5 a. m. the temperature outside the orchard stood at 22°, while at the same time the temperature in the orchard ranged from 26° to 29°. Several readings were taken in different parts of the orchard between 4:30 and 5 a. m., the readings varying somewhat with the exposure. On the windward side the temperature was only slightly above that observed outside the orchard, while on the leeward side it was from 5° to 7° higher. A marked difference was noted in the readings at different elevations. On the ground in the orchard the readings were but slightly above the outside readings, while at an elevation of 3 or 4 feet it was from 3° to 4° higher. Up in the trees, among the blossoms, I obtained several readings of 32°, and some as high as 34°. At this time the reading outside the orchard was as low as 20° A heavy frost formed on the grass in the orchard, and ice formed even inside the fruit buds.

It became apparent to me that the smudge pots were not lighted as soon as they should be, and it took too long to get them all lighted. Thus the temperature was allowed to get too low before any appreciable amount of heat was generated. With the pots only one-third open, the temperature was raised but little, but when they were opened wider the temperature immediately began to rise.

A minimum temperature of 19° was registered outside the orchard, but I do not believe the temperature in the trees among the blossoms fell below 25°. At the height of the effect of the smudging temperatures of from 28° to 34° were maintained among the blossoms.

Reports, more or less fragmentary, were received from a number of growers, all indicating that beneficial results had been obtained, but in no other orchard were careful observations made.

The temperature did not fall so low again during the spring, and no opportunity was presented later for studying the effect of smudging under severe conditions.

The writer spent the night of May 15-16 in the orchard of the Manville Fruit Company, near Ustick. About 1 a. m. the temperature began to rise and it remained above 40° till after 4 a. m. Although it was evident that no damage would result from the frost, Mr. Hurst, the manager of the orchard, kindly offered to fire up the pots on an acre of ground (100 pots), in order to enable me to make some comparative readings. While this was being done the temperature fell rapidly, and by 5:30 a. m. it had fallen to 32° in the lowest part of the orchard and heavy frost was forming on the grass. Comparative readings were taken in and out of the heated area at frequent intervals for about one hour. These were rather unsatisfactory, owing to the fact that there was considerable difference in the sensitiveness of the different thermometers in use, and the heated area was too small for best results. However, the readings seemed to indicate that over the heated area the temperature was about 4° higher than elsewhere. No frost formed on the grass in the heated area, while over most of the remainder of the orchard there was a considerable deposit of frost.

Such investigations as it has been possible to make lead to the following conclusions:

1. Orchard heating in the Boise Valley is entirely practicable, and by its intelligent use serious loss from frost can be practically eliminated.

2. To achieve the best results there should be a strong local organization cooperating with the Weather Bureau, and action should be taken to plant orchards in large blocks, the larger the better.

3. By means of a large number of standard thermometers placed among the growers, and mounted in a uniform manner, a thorough temperature survey of the valley would be possible. On cold nights the association of growers would therefore be able to report to the Weather Bureau at frequent and regular intervals, the temperature at representative places in the valley.

4. The temperature readings at the Weather Bureau station, being from thermometers mounted 78 feet above the ground, are of little value in determining conditions in the orchards, there being at times differences of 10° or more between these readings and the actual temperatures in the orchards. Arrangements should be made for a sod exposure of the thermometers, or at least for an extra set with such an exposure, on the lawn near the office, for the better information of the Weather Bureau office in determining the probability of frost.

5. The matter of wind direction and velocity plays such an important part in the frost problem that it is believed that a wind record should be kept at some point in the heart of the orchard region.

The following extracts from letters received from representative fruit growers may be of interest:

We found the heaters absolutely essential when the low temperatures came. As a result of their use we have saved the entire crop, so much so that it has been necessary to thin, and thin heavily. We feel that the cooperation of you and your office had as much to do with our frost fighting success as the use of the heaters themselves.—*Olin M. Kiggins.*

I have found the Weather Bureau, under your direction, a great help to me in the past year. * * * I have come to depend greatly upon your advice. The data that you gave us concerning the rising and falling of the temperature in the latter part of the night during April and May helped us to know when to light our smudge pots and thus proved a saving to us of both strength and oil. * * * I feel that if the farmers would cooperate with you in reporting the conditions hourly during the night all over the valley much more benefit might be received. * * *—*B. F. Hurst, Manager, Manville Fruit Company.*

I have no criticism whatever on the work of the Weather Bureau in our behalf this year. For the director to be at his station night after night for a week at a time was certainly appreciated by the fruit growers of the Boise Valley. For my part, I was in close touch with the station and for several nights every hour, and the station reports saved me at least 3 heatings, or rather lightings of the pots.—*W. N. Yost.*